Aeroacoustic source analysis in a corrugated flow pipe

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Abstract

This study is focused on a phenomenon often encountered in flow carrying pipes, since flow instabilities caused by geometric features may generate acoustic signals and thereafter interact with these signals in such a way that powerful pure tones are produced. A modern example is found in the so-called “singing risers”, or the gas pipes connecting gas production platforms to the transport network. But the flow generated resonance in a fully corrugated circular pipe may be silenced by the addition of relatively low frequency flow oscillations induced by an acoustic generator. Experiments reported here, aimed at investigating in more detail the coupling between the flow in the pipe, the acoustically generated flow oscillations and the emitted resulting noise, are performed in a specifically designed facility

Introduction

Due to their flexibility and local stiffness, corrugated pipes are used in many engineering applications. It is known that if the pipes carry a flow of dry gas, whistling sounds associated with the pipes' length resonances may develop. This phenomenon is used positively in musical toys like the Hummer but represents a problem in engineering applications as high sound levels and associated structural vibrations may develop. A well-known example is the "singing riser" phenomenon observed on some natural gas installations in the North Sea. After starting singing a riser is generally damaged after 2 or 3 hours and then represent a major problem in gas and oil industry

The aim of the present research is to study both the acoustic and aerodynamic fields within a corrugated pipe under singing conditions using both acoustical and optical means. A rectangular cross section pipe has been manufactured for this purpose. It is made by transparent Plexiglas, thereby allowing direct inspection of the aerodynamic field by a PIV (Particle Image Velocimetry) technique. We also wanted to investigate more fully a previously published finding, mainly that adding a strong signal at a frequency very much lower than the whistling frequency of the pipe, under some conditions, will quench the whistling. To obtain a high acoustic oscillation at a low frequency, a 17m long resonance tube is added to the system. The resonance tube can be excited by a set of loudspeakers to give the corrugated pipe a global oscillation around 14Hz

The experimental facility under study is made of a low speed wind tunnel whose fan rotation speed ensures a flow velocity up to *25 m/s*. The tunnel is connected to a corrugated rectangular pipe of *2 m* length, prolonged by a loudspeaker made of two push-pull sub-woofers itself ended by an open resonator of *17 m* length whose resonance frequency is around *10 Hz*. The rectangular riser is made of Plexiglas plates. The riser has lateral width *D = 20mm*, height *B = 100mm* and length *L = 2 m*. The lateral plates are machined in order to make a wall with a rectangular corrugation of pitch length *Pt=20mm* that is repeated all along the pipe.

Results

A low-frequency acoustic field (around *10 Hz*) leads to a dramatic reduction of the riser whistling. During the mitigation, the very low frequency acoustic mitigation induces a flow speed modulation around mean velocity. This modulation dramatically changes the nature of the sound fields created by the riser, from intense tone to much quieter periodic whistling. Under this mitigation, a residual fluctuation was measured on both the sound field inside the pipe and the flow velocity at its entry. By eliminating the low frequency forcing term on both signals and by correlating them, we have observed the maximum correlation for a propagation time of *0.007 s*. This time is very close to that necessary for a wave to propagate from the entry to the exit at the measured sound celerity of *300 m/s*. This is an obvious proof that the noise source is at the entry of the pipe. We have also observed is that the signal is made of quasi mono frequency packet wave and that each one is made of a set of shorter packets each separated from the previous and followed ones by a time of about *0.014 s* (i.e. twice the flying time to the pipe exit), each of it having an intensity increasing until it reaches a maximum and decreasing after that maximum. The explanation is that a small monochromatic acoustic perturbation is emitted at the entry by the flow-cavity interaction, propagates toward the exit end, at an apparent velocity of about *300 m/s* (taking *0.007 s* to reach the exit), reflects and back propagates to the entry, reflects again and increases in intensity by coupling with the entry source, and so on, until the entry source vanishes because of the flow velocity mitigation. After that, the wave packet continues to reflect at both ends of the riser, but loses part of its energy by sound radiation and then decreases in amplitude

This observation has not only confirmed that the origin of the riser whistling lies close to its entry but also allows better mitigation by controlling the low-frequency acoustic field to limit the amplification by wave superposition of the various reflected wave packets.

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